EPA-420-R-80-109

Automotive Testing Laboratories, Inc.

Final Report

Contract No. 68-03-2891
Task Order #1

Tests on Five Diesel Passenger Cars at High Altitude

August 25, 1980

prepared for:
U. S. Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, MI 48105

651 chambers road, suite 200 303-343-8939 aurora, colorado 80011

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ABSTRACT

Under this Task Order a series of emission and fuel economy tests were performed on a group of five diesel passenger cars. The test sequence consisted of the Federal Test Procedure (FTP) followed by the Highway Fuel Economy test (HFET). In addition methane emissions were measured during the FTP and particulate measurements were made during both the FTP and the HFET. The intent of the Task Order was to assess the effect of altitude on the emissions of diesel powered vehicles. The low altitude tests were performed by the Environmental Protection Agency (EPA) at the Ann Arbor, Michigan facility. The high altitude tests were performed by Automotive Testing Laboratories, Inc. (ATL) at their Aurora, Colorado facility.

This report presents the results of the high altitude tests.

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1. INTRODUCTION

The United States Environmental Protection Agency (EPA) is charged under the provisions of the Clean Air Act with responsibility for the control and prevention of air pollution. In order to fulfill these responsibilities the EPA designs, conducts and promotes surveys and studies of air pollution sources.

National programs to characterize and reduce air pollution from mobile sources are developed and implemented through the EPA's Emission Control Technology Division (ECTD). Mobile emission control strategies developed by the ECTD are based, in part, on projections of nationwide motor vehicle emissions. These projections are derived from surveys designed to obtain emission data from representative samples of in-use vehicles.

With the recent changes in standards relative to emissions and fuel economy there has been an increase in the population of diesel powered light duty vehicles. With this increase the affects of diesel powered vehicles are of relatively greater importance. Accordingly, the EPA issued a Task Order contract to gather information regarding the effects of altitude on gaseous and particulate emissions from diesel passenger cars. This report describes the design and conduct of the project and presents test results.

2. TECHNICAL DISCUSSION

2.1 PROGRAM OBJECTIVES

The objective of the program was to provide emission level data on a sample of five diesel powered passenger cars. Gaseous and particulate emissions were measured using the Federal Test Procedure (FTP) and the Highway Fuel Economy Test (HFET); additionally methane measurements were taken during the FTP. These data will later be compared, by the EPA, with data taken at the EPA Ann Arbor, Michigan laboratory.

2.2 PROGRAM DESIGN

The program design was provided by the EPA in the form of the Scope of Work. Five vehicles were specified for the program as "used, late model diesel-powered passenger cars; one each of the following manufactures: Volkswagen, Mercedes Benz, Peugot, Oldsmobile, and "Optional Vehicle." The model and engine size of each vehicle were to be determined by the Project Officer after a number of prospective test vehicles were identified. The Optional Vehicle was also to be determined by the Project Officer.

The vehicles were to be obtained in a low altitude area and delivered to the EPA Ann Arbor facility for low altitude testing. Following low altitude testing the vehicles were to be transported to the Denver laboratory for high altitude testing. The following test sequence was specified:

- o 1975 Federal Test Procedure (including Methane Analysis)
- o Highway Fuel Economy Test
- o Particulate testing in conjunction with both the FTP and HFET

Due to the small fleet an additional constraint was placed on the program in that each vehicle was to undergo a minimum of two of the specified sequences. If the results of the two cold start FTP tests differed by more than 10% a third test sequence was to be performed.

2.3 TEST VEHICLE PROCUREMENT

The test vehicles were obtained through the services of a leasing firm in St. Louis, Missouri. Constant contact was maintained with the Project Officer throughout the vehicle selection. The five vehicles selected are described as follows:

241 1980 Volkswagen Rabbit: 4 cylinder; 90 CID; Manual 5 speed; VIN - 17A0815408; Engine Family-D; Odometer-005579

242 1979 Oldsmobile Cutlass Supreme: 8 cylinder; 260 CID; Automatic transmission; VIN - 3R47P9M535761; Engine Family-930H9; Odometer-08930

243 1979 Oldsmobile Cutlass Supreme: 8 cylinder; 260 CID; Automatic transmission; VIN - 3R47P9M540008; Engine Family-930H9; Odometer-13301

244 1974 Peugot 504: 4 cylinder; Manual 4 speed; VIN 504D90-1759613; Odometer-73252

245 1977 Mercedes Benz 240D: 4 cylinder; 147 CID; Automatic transmission; VIN - 123.123-12015320; Engine Family-77/2/L-4D/2.4; Odometer-052206

Subsequent to the vehicle acquisition the vehicles were transported from St. Louis to the Ann Arbor laboratory. Test fuel was put into the fuel tanks, the vehicles were prepared for testing and the testing was conducted (excluding Methane testing). The vehicles were then transported to Denver for altitude testing.

2.4 VEHICLE TEST FACILITIES AND EQUIPMENT

The ATL test facilities and associated equipment utilized in this Task Order are located at 19900 East Colfax Avenue, Aurora, Colorado. The laboratory is at an altitude of 5,480 feet above sea level. Prior to testing a representative of the EPA visited the laboratory where facility and equipment procedures were checked. Typical emission testing equipment was used in the conduct of the program excepting the particulate measuring apparatus which is discussed below.

2.4.1 Particulate Emission Test Equipment

The particulate emission sampling equipment consisted of a dilution air filtration system, a tunnel, and sample collection system. Except for the filters, which are of filter paper and charcoal construction, the filter housing is of stainless steel construction. The tunnel is also of stainless steel construction; the overall length of the tunnel section is 12 feet and it is 10 inches in diameter. The sampling system is a dual pump design which allows collecting separate samples during each phase of the FTP. The sampling system operates as follows:

Dilution air enters the assembly and is filtered. A particle, a charcoal and a final filter assembly is provided for this purpose. After filtration, the dilution air enters the tunnel where it is combined with exhaust from the vehicle. Vehicle exhaust enters the tunnel through a 4 inch diameter, 90 degree bend elbow. The point at which the exhaust is introduced to the dilution air stream is about 1 and 1/2 feet from the outlet of the dilution air filter box. At this introduction point a mixing orifice is installed. The mixing orifice, of 7 inches in diameter, is situated in the plane described by the 4 inch, 90 degree exhaust introduction tube bend termination. This plane is perpendicular to the round wall of the tunnel. From this mixing plane the diluted exhaust flows to the plane at which it enters the transition piece which reduces stream diameter from the 10 inches of the tunnel to the 4 inches of the CVS collection tube. This transition is made in about 1 and 1/2 feet. The only obstruction from the mixing point to the start of the transition piece is the sample probe. The CVS collector tube, also of stainless steel construction, carries the dilute exhaust into the CVS. During sulfate testing, dilution air from the CVS filter box is closed off by means of a flapper valve that is pneumatically activated. Beyond the flapper valve, dilute exhaust flow within the CVS is normal. The tunnel and remote dilution box is merely an extension of normal flow paths within the CVS.

The sample probes are 1/2 inch diameter stainless steel tubes. These tubes face upstream and originate about 10 feet from the dilution air exhaust mixing point. From its point of origin the tube runs parallel to the tunnel for about five inches, makes a 45 degree bend, continues another 3 inches, makes another 45 degree bend and passes through the tunnel wall. Immediately outside the tunnel wall, the filter assembly, which holds a 47 millimeter diameter "Pallflex" filter (type 460A20), is situated. The particulate emissions are collected on this filter. From this point the filtered sample continues through an on-off valve, a pump, a flow control valve, a flowmeter and a dry gas meter. The on-off valve is used to start and stop sample flow at the beginning and end of the test phase. The pump moves sample through the filter. The flow control valve is used to regulate the sample stream flow. This valve is manually adjusted frequently and as necessary during the test. The dry gas meter is used to totalize sample flow during the test phase. A solenoid valve wired into the bag sample system directs the flow through one of two filter assemblies, allowing separate collection of particulate emissions during each of the three phases of the FTP.

2.5 LABORATORY TEST PROCEDURES

Each vehicle received a prescribed sequence of test procedures during the course of the work effort. These procedures and others associated with the conduct of the program include the following:

Vehicle Preparation

Vehicle Preconditioning

Federal Test Procedure (including Methane and Particulate tests)

Highway Fuel Economy Test (including Particulate tests)

Details on these tests and preparations are presented in the following sections.

2.5.1 Test Vehicle Preparation

The basic vehicle acceptability inspection was performed by the leasing company at the time the vehicles were acquired. This included such items as transmission fluid and engine coolant levels, integrity of the exhaust system, tire wear, etc. Following acceptance into the program the vehicles were transported to the EPA Ann Arbor facility for low altitude testing. In Ann Arbor the final vehicle preparations were made; Diesel II fuel was put in the fuel tank, the tires were inflated to test pressures, etc.

2.5.2 Vehicle Preconditioning

At the ATL laboratory preconditioning for the first test sequence on each vehicle consisted of vehicle operation on the dynamometer following the LA-4 driving cycle. This method was chosen in order that the vehicle operator became acquainted with the characteristics of the vehicles. On subsequent tests, the preceding test was deemed sufficient preconditioning. Following the vehicle operation the vehicle was placed in soak for a 12 to 36 hour period. The fuel placed in the fuel tank at the EPA laboratory was used in all tests.

2.5.3 Federal Test Procedure (Mass Exhaust Emission Test)

The Federal Test Procedure was performed in accordance with procedures specified in 42 Federal Register 124. Preconditioning requirements for this test include a 12 to 36 hour soak period in an area with an ambient temperature between 20 and 30 degrees Centigrade (68 to 86 Fahrenheit). Each vehicle remained stationary while soaking with the ignition in the unlock position and the transmission in neutral. Doors were unlocked and the window on the driver's side was rolled down.

None of the five vehicles acquired for this work effort received those segments of the FTP which deal with evaporative loss measurements. Consequently, following the soak period, test vehicles were moved to the dynamometer for the mass exhaust emission segment of the FTP.

Before the test vehicle was placed on the dynamometer and secured, the proper inertia weight and load adjustments were set. During testing, the vehicle hood remained open and a cooling fan was placed in front of the engine approximately six to twelve inches from the vehicle grille.

The Federal Test Procedure consists of three segments: the cold transient stage, the cold stablized stage and the hot transient stage. Sampling during the intital cold transient portion was begun simutaneously with engine crank. This phase continued for 505 seconds at an average speed of 25.6 miles per hour over a cumulative distance of 3.59 miles. At the 505 second point, the exhaust sample was diverted from the first sample bag of the Constant Volume Sampler (CVS) to the second. This marked the beginning of the cold stabilzed portion of the test. This segment covers 3.91 miles at an average speed of 16.0 miles per hour. Its duration is 869 seconds. At the end of this phase the engine was stopped, sampling was terminated and the vehicle was soaked on the dynamometer for ten minutes. After soaking, the vehicle was restarted and sampling was switched to the third CVS bag for 505 seconds at an average speed of 25.6 miles per hour. CVS sample and background bags were analyzed within ten minutes after completion of each phase of the test.

2.5.3.1 Methane Test Procedure - Each bag sample collected during the FTP was analyzed for methane content using a Bendix 8205 analyzer.

2.5.4 Highway Fuel Economy Test Procedure

The HFET was begun with the vehicle in a warmed condition, having been driven at least 7.5 miles on the dynamometer within the last fifteen minutes. The vehicle was first preconditioned on the dynamometer at 50 mph for three minutes. Within one minute of the end of preconditioning, the car was brought to idle and the test begun.

One sample is taken during the HFET, which is 765 seconds long and covers 10.2

miles. Fuel economy is calculated from emission results using the carbon balance equation. Load settings and inertia weights are identical to those used for the Federal Test Procedure.

2.5.5 Particulate Test Procedure

Samples of particulate exhaust emissions were collected for each of the three phases of the FTP and for the HFET using the equipment described in Section 2.4.1. For the FTP both sample systems were used. During the cold transient phase dilute exhaust sample was drawn through the filter in filter assembly #1, at the 505 second point the cold stablized phase began and sample was drawn through the filter in filter assembly #2. During the 10 minute soak a new filter was placed in filter assembly #1 which was then used during the Hot Transient phase. Filter assembly #1 was used during the HFET. The weight of particulates collected were determined by weighing the filter before the test and the combined particulate and filter after the test.

2.5.6 Special Test Consideration and Procedures

The Task Scope of Work specified a replicate test on each vehicle which was used to determine if a third test might be required. Preliminary test results dictated additional tests in some cases. In these cases all test results are given in this report along with appropriate comment. In other cases certain portions of the sequence were invalid; in these cases the valid portions are presented. An example of this is a test in which the particulate sampling system malfunctioned invalidating the particulate measurements but had no effect on the rest of the results.

2.6 DATA PROCESSING PROCEDURES

Accumulated raw test data and associated materials received a systematic review of each test point in the task from initial generation to final processing. These data accumulation, review, and reduction procedures are described below.

2.6.1 Data Collection

Emission test procedures and laboratory conditions were monitored and controlled through the use of strip chart recorders. These units provided a constant read-out of data and also served to document test activities for later review. Test parameters registered on the recorders included emission analyzer outputs, wet and dry bulb mesurements of air directed to the front of test vehicles and dilute exhaust stream temperatures. Driver/vehicle performance traces were also documented on a strip chart recorder and include speed calibrations and subsequent calibration checks performed before and after each test.

Sample flow rates, gas meter temperatures and readings and other data relative to the particulate system were recorded on data forms.

A NOVA 2 minicomputer was utilized to collect and integrate CVS sample and background bag emission data. Speed/time profiles were also generated for each test schedule by the computer and produced on the driver/vehicle performance trace. In addition to these functions, the computer totalized and recorded CVS mass pump revolutions during each exhaust emission test segment.

Movement of each test vehicle through segments of the work effort was controlled and documented through various raw data sheets. All data forms were collected in test packets which were assigned to each vehicle prior to testing. As testing progressed, relevant sheets were completed, signed and returned to the packet by the appropriate technician. Included in the packet were: all raw data sheets used to identify the vehicle, raw data sheets used during tests, analyzer strip chart recordings, computer system sheets and magnetic tapes and all appropriate temperature strip chart recordings.

Laboratory personnel were also furnished a form indicating the daily test schedule including the order each vehicle was to be tested and the estimated duration of each test segment. Preconditioning personnel were also furnished with a similar schedule indicating the time each vehicle was to be placed in soak.

Data forms used to collect test results are presented in Appendix A.

2.6.2 Data Review and Editing

Vehicle data was reviewed immediately following test completion. This included an inspection for completeness, accuracy, and compliance with temperature and speed tolerances. A preliminary data reduction of the test at this time allowed a reasonableness check of test results by the quality audit inspector.

2.6.3 Calculation of Test Results

2.6.3.1 Federal Test Procedure Emission Data - Mass emission test results were calculated using equations specified in 42 Federal Register 124. Calculations were made using the standard transient and stabilized mileages of 3.59 and 3.91 miles respectively rather than actual measured distances traveled. The methane calculations were made using the formulae for hydrocarbons but using a density of 18.89 grams per cubic foot. Fuel economy data were calculated using the carbon balance equation.

2.6.3.2 Highway Fuel Economy Data - Results of the Highway Fuel Economy Test were calculated using Federal Register equations and a distance constant of 10.242 miles per test. Fuel economy was calculated using these mass emissions and the carbon balance equation.

2.6.3.3 Particulate Test Data - Results for this test were calculated using the flow rates of the sampling system, filter weights, meter readings and other collected information using the equations presented in Appendix B.

The results presented here are of a quantitative nature. The filters have been sent to the EPA for qualitative analysis.

3. TEST RESULTS

The results of the tests on the five diesel passenger cars are presented in tabular form on the following pages.

All emission results are in grams per mile and the fuel economy values are in miles per gallon.

VEHICLE 241: VOLKSWAGEN RABBIT

Test #D3778 Date: 7/14/80

Test aborted: Same particulate filter used for FTP HT bag and HW test. HW was not sampled.

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	.364	3.001	1.012	326.9	30.58	.0714	.4142
CS	.654	1.186	1.180	267.7	37.46	.0129	.2313
HT	.669	2.497	1.068	274.5	36.27	.0459	——
FTP	.599	1.917	1.115	281.8	35.49	.0339	——
HFET	——	——	——	——	——		——

Test #D3807 Date: 7/15/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	.723	2.472	.893	304.1	32.80	.0529	.6112
CS	.432	1.109	1.132	273.7	36.75	.0109	.1589
HT	.446	1.782	.940	269.2	37.22	.0397	.3774
FTP	.496	1.573	1.030	278.8	35.98	.0274	.3127
HFET	.274	1.297	.675	217.6	46.14		.3076

Test #D3877 Date: 7/18/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	1.204	3.782	1.112	337.4	29.31	.1053	.5451
CS	.545	1.072	1.448	307.2	32.76	.0208	.5636
HT	.631	2.058	.941	265.6	37.57	.0652	.3891
FTP	.704	1.899	1.241	302.0	33.12	.0503	.5122
HFET	.424	1.752	.765	237.0	42.20		.4281

Test #D3991 7/25/80

Test aborted: Particulate gas meter malfunction

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	.959	3.210	.948	316.3	31.37	.0924	.7098
CS	.444	1.346	1.108	273.0	36.79	.0199	——
HT	.445	2.335	.955	277.7	35.99	.0623	.5016
FTP	.553	2.000	1.033	283.2	35.32	.0464	——
HFET	.357	1.365	.881	240.9	41.68		——

Test #D4021 Date: 7/29/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	.746	3.182	.929	316.3	31.43	.0841	.5999
CS	.366	1.315	1.099	260.5	38.58	.0237	.2234
HT	.532	2.447	.922	266.7	37.38	.0839	.4676
FTP	.490	2.008	1.016	273.7	36.55	.0526	.3675
HFET	.326	1.244	.916	247.7	40.59		.2831

VEHICLE 242: OLSMOBILE CUTLASS

Test # D3768 Date: 7/11/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	2.008	2.847	1.302	565.8	17.65	.0521	1.4068
CS	1.572	2.135	1.295	490.2	20.41	.0323	.6462
HT	1.186	2.026	1.283	461.4	21.73	.0202	1.1482
FTP	1.556	2.252	1.294	497.9	20.10	.0331	.9397
HFET	.493	1.082	1.197	360.3	27.99		.6281

Test #D3876 Date: 7/18/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	1.542	2.821	1.351	539.9	18.53	.0472	1.7796
CS	1.568	2.148	1.323	471.7	21.20	.0315	.4399
HT	1.083	1.988	1.305	450.6	22.26	.0204	1.2673
FTP	1.430	2.243	1.324	480.0	20.85	.0317	.9414
HFET	.512	1.012	1.232	351.5	28.69		.7012

Test #D3976 Date: 7/24/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	1.421	2.617	1.267	552.5	18.13	.0418	1.6451
CS	1.269	2.071	1.265	471.5	21.25	.0294	.7700
HT	.810	1.849	1.233	458.7	21.92	.0180	1.1949
FTP	1.175	2.123	1.257	484.7	20.69	.0288	1.0660
HFET	.399	1.028	1.160	350.2	28.82		.8404

VEHICLE 243: OLDSMOBILE CUTLASS

Test #D3780 Date: 7/14/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	1.470	3.646	1.593	544.5	18.34	.0560	2.6429
CS	1.027	2.310	1.594	474.5	21.14	.0324	1.5819
HT	.774	2.510	1.634	460.8	21.78	.0243	2.0997
FTP	1.049	2.639	1.605	485.2	20.65	.0350	1.9415
HFET	.405	1.325	1.522	353.8	28.49		1.1362

Test #D3954 Date: 7/23/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	1.341	3.266	1.511	546.3	18.31	.0539	2.3473
CS	.825	2.196	1.534	480.4	20.92	.0293	1.5071
HT	.649	2.495	1.528	463.7	21.67	.0256	1.5666
FTP	.884	2.498	1.527	489.4	20.51	.0333	1.6962
HFET	.324	1.215	1.386	340.2	29.66		1.1070

VEHICLE 244: PEUGEOT

Test #D3783 Date: 7/14/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	6.502	11.823	1.100	474.3	19.82	.3799	3.1557
CS	7.769	6.863	.881	434.5	21.65	.1272	2.1536
HT	5.791	9.106	.987	432.2	21.89	.2674	2.4189
FTP	6.969	8.496	.955	442.1	21.31	.2175	2.4322
HFET	1.948	3.739	1.113	387.3	25.48		.8245

Test #D3988 Date: 7/25/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	6.664	13.902	1.121	493.5	18.97	.4449	3.3218
CS	7.015	7.076	.966	449.0	21.10	.1366	2.1661
HT	5.429	9.960	1.003	442.1	21.42	.3049	2.2786
FTP	6.510	9.268	1.008	456.3	20.70	.2460	2.4347
HFET	1.801	3.365	1.057	375.8	26.31		.5501

VEHICLE 245: MERCEDES BENZ

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	.978	1.537	1.741	496.0	20.29	.0126	.7279
CS	.820	1.042	1.435	363.3	27.69	.0113	.4780
HT	.481	.981	1.627	413.5	24.43	.0067	.2969
FTP	.760	1.127	1.551	404.3	24.91	.0103	.4801
HFET	.267	.690	1.721	373.8	27.08		.2102

Test #D3875 Date: 7/18/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	.741	1.130	1.744	454.9	22.17	.0080	.5537
CS	.731	1.036	1.386	347.3	28.97	.0119	.2654
HT	.499	.840	1.575	377.3	26.76	.0079	.4242
FTP	.670	1.002	1.511	377.7	26.68	.0100	.3681
HFET	.289	.586	1.695	345.3	29.32		.2503

Test #D3967 Date: 7/23/80

	HC	CO	NOx	CO2	MPG	CH4	Particulate
CT	.513	1.124	1.679	475.3	21.26	.0128	.7032
CS	.578	1.025	1.353	354.8	28.41	.0119	.5234
HT	.359	.836	1.519	394.4	25.64	.0072	.4852
FTP	.505	.994	1.465	390.4	25.86	.0108	.5500
HFET	.214	.612	1.610	355.0	28.54		.2176

APPENDIX A

DATA FORMS

CVS MASS EMISSION TEST

PROJECT: ________

TEST CELL: ________

TEST TYPE: 75F COLD74 HOT74 COLD72 HOT72 HOT505 HFET

75D COLD74D HOT74D COLD72D HOT72D HOT505D HFETD (DIESEL)

75M COLD74M HOT74M COLD72M HOT72M HOT505M HFETM (MODALS)

TEST NO. ____________ VEHICLE NO. ____________ DATE ___/___/___

BAROMETER ____________ *PUMP INLET PRESSURE* ____________

COMMENTS: ____

____

		NO_x	HC	CO_2	CO
1st BAG	BKGRND				
	SAMPLE				
2nd BAG	BKGRND				
	SAMPLE				
3rd BAG	BKGRND				
	SAMPLE				

	BLOWER REV.	DB TEMP.	WB TEMP.	DISTANCE
1st BAG				
2nd BAG				
3rd BAG				

IF MODAL CIRCLE MODAL TYPE: 62D 62C 80D CHRY

MODEL YEAR ________ ODOMETER ________ EVAP. ________ MAN. VAC. ________

VEH. MAKE ________ OPERATOR ________ MODAL ________ IDLE RPM ________

C.I.D. ________ DRIVER ________ FUEL ________ IDLE CO ________

TRANS. ________ TIME ________ CARB. ________ LOAD @ 50 ________

INT. WT. ________

NOTES: ____

____

KEY OFF TIME ________

DATE ________

AUTOMOTIVE TESTING LABORATORIES, INC.
19900 E. COLFAX, AURORA, COLO. 80011

PARTICULATE TEST

TEST # ____________ VEHICLE # ____________ DATE ____________

Barometer ____________

Cold Transient	Gas Meter No. ______	Filter WT.	
	Flow Rate ______	Before	____
	Initial Reading ______	After	____
	End Reading ______		
	Meter Temp ______		
Cold Stabilized	Gas Meter No. ______	Filter WT	
	Flow Rate ______	Before	____
	Initial Reading ______	After	____
	End Reading ______		
	Meter Temp ______		
Hot Transient	Gas Meter No. ______	Filter WT	
	Flow Rate ______	Before	____
	Initial Reading ______	After	____
	End Reading ______		
	Meter Temp ______		
Highway Fuel Economy	Gas Meter No. ______	Filter WT	
	Flow Rate ______	Before	____
	Initial Reading ______	After	____
	End Reading ______		
	Meter Temp ______		

APPENDIX B

PARTICULATE EMISSIONS CALCULATIONS

The total particulate emissions in grams for a given test phase are calculated as follows:

$$\text{Total Particulates} = \frac{Vmix}{GMV} \times (FW_A - FW_B)$$

Where: Vmix is the total dilute exhaust volume in cubic feet per test phase corrected to standard conditions.

GMV is the total particulate system sample volume in cubic feet per test phase corrected to standard conditons.

FW_A is the weight of the filter and particulates in grams collected during the test phase.

FW_B is the weight of the filter in grams before the test.

Vmix is calculated as specified in the Federal Register.

GMV is calculated as follows:

$$GMV = (MR_E - MR_I) \times \frac{BAR}{29.92} \times \frac{530}{460+T_G} \times MCF$$

Where: MR_E is the dry gas meter reading in cubic feet at the completion of the test phase.

MR_I is the dry gas meter reading in cubic feet at the beginning of the test phase.

BAR is the ambient barometric pressure in inches Hg.

T_G is the temperature of the gas flowing through the dry gas meter in degrees Fahrenheit.

MCF is the dry gas meter correction factor obtained through laminar flow element calibration.

The particulate emissions in grams per mile are found per test phase by dividing the total grams per phase by the standard distance constant. The weighted emission results are found by applying the standard distance constants and using the weighting factors and equations given in the Federal Register.